REPORT No. 109

EXPERIMENTAL RESEARCH ON AIR PROPELLERS, IV

By W. F. DURAND and E. P. LESLEY
Leland Stanford Junior University, California

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INTRODUCTION.

The purpose of the investigations on the performance of air propellers described in the following report was the extension in certain directions of the field covered by the previous investigations (Reports Nos. 14, 30, 64) and the testing of certain special forms.

The forms included under the present report are characterized as follows:

Number.	Diameter.	Pitch.	Mean blade width.	Shape of blade.	Blade section.
	Inches.	*Inches.*			
139	36	10.8	0.15r	2	Noncambered.
142	36	32.4	.15r	Special.	Do.
143	36	32.4	.15r	Special.	Do.
144	36	10.8	.20r	2	Do.
145	36	10.8	.15r	1	Do.
146	36	10.8	.20r	1	Do.
148	36	25.2	.25r	2	Do.
150	36	25.2	.25r	2	Do.
151	36	(1)	.15r	2	Do.
152	36	(2)	.15r	2	Do.

[1] Plane driving face 17°–10 feet. [2] Plane driving face 21°–40 feet.

It will be noted that propellers 139, 144, 145, 146 are similar in all respects to Nos. 3, 4, 1, 2 of Report No. 14 except in pitch ratio which is here 0.3. These forms thus serve to extend to this pitch ratio the various results covering thrust and torque coefficients and efficiency, for the four families representing the combination of these two blade forms and blade areas. These results, together with those previously tested, thus give a series of values in each of the four families for the six nominal pitch ratios, 0.3, 0.5, 0.7, 0.9, 1.1, 1.3.

Propeller 148 is of form No. 2 (Report No. 14), or with curved and somewhat tapering outline. Its mean width, however, is 0.25r or 25 per cent greater than the A_2 of Report No. 14. Propeller 150 is of form No. 1 (Report No. 14), or with nearly straight parallel sides, and has also a mean width of 0.25r. These two propellers serve, with the two mean widths previously reported on, to give two series of values for varying blade area corresponding to mean widths, respectively, of 0.15r, 0.20r, 0.25r.

Propellers 151, 152 are of form and area the same as F, A, of Report No. 14, but with face flat or unwarped. For propeller 151, the blade is set at such an angle as to give, at the 13-inch radius, a pitch of 25.2 inches, or the same as a 0.7 pitch ratio propeller of 36 inches diameter. For propeller 152 the blade is set to give similarly, at the 13-inch radius, a pitch of 32.4 inches, or the same as a 0.9 pitch ratio propeller of 36 inches diameter.

Propellers 142 and 143 have a section and pitch identical with propeller No. 1 of Report No. 14. They have contours, however, as shown on plates I, II, the sections being distributed along a cycloidal curve instead of a radial line, as in the case of No. 1. These forms were intended to test certain ideas submitted to the committee by Brig. Gen. H. H. C. Dunwoody (retired).

RESULTS OF TESTS.

The various results are given in the form of curves of the thrust and torque coefficients T and Q and efficiency ρ.

The thrust and torque coefficients are defined by the equations

$$T_c = \frac{gT}{\Delta V^2 D^2} \tag{1}$$

$$Q_c = \frac{gQ}{\Delta V^2 D^3} \tag{2}$$

$$\rho = \frac{TV}{2\pi NQ} \tag{3}$$

The introduction of the factor g serves to render the coefficients nondimensional and thus independent of the system of units employed, provided they are homogeneous.

The values of T_c, Q_c, and ρ thus defined are given on curve sheet diagrams Nos. III to XII.

DISCUSSION OF RESULTS.

As would be expected, the efficiencies given by the propellers of 0.3 pitch ratio are so displaced relative to the values of V/ND that for low values of this abscissa the efficiency is higher and for high values lower, as compared with the efficiencies with forms of higher pitch ratio. The maximum efficiency reached, however, is definitely less than those for higher pitch ratios, thus falling in general line with the results for the series of pitch ratios 0.5, 0.7, 0.9, 1.1, 1.3.

The wide blade forms 148 and 150 have efficiency curves falling somewhat below those with lesser area but with similar forms otherwise, thus indicating the increasing influence due to skin resistance. These efficiency curves have, however, a somewhat lengthened range, corresponding to the increased value of the dynamic pitch.

Forms 151 and 152 show efficiencies definitely below those for the most nearly related helicoidal forms. Over the working range, however, the differences are relatively small and the tests indicate the close degree of approach to helicoidal forms realized by these nonwarped blades.

Propellers 142 and 143 show efficiency torque and thrust curves very similar to those for propeller No. 1. Propeller No. 142 having a convex leading edge, bends under load in such manner as to decrease the pitch. This operates to give, as it should, a somewhat lower maximum efficiency than for No. 1, but somewhat higher efficiencies for large values of the slip (low values of V/ND).

On the other hand, propeller No. 143 with concave leading edge increases in pitch when under load with the corresponding result of showing a somewhat higher maximum efficiency as compared with No. 1, but definitely lower efficiencies over the working range of moderate to small values of V/ND.

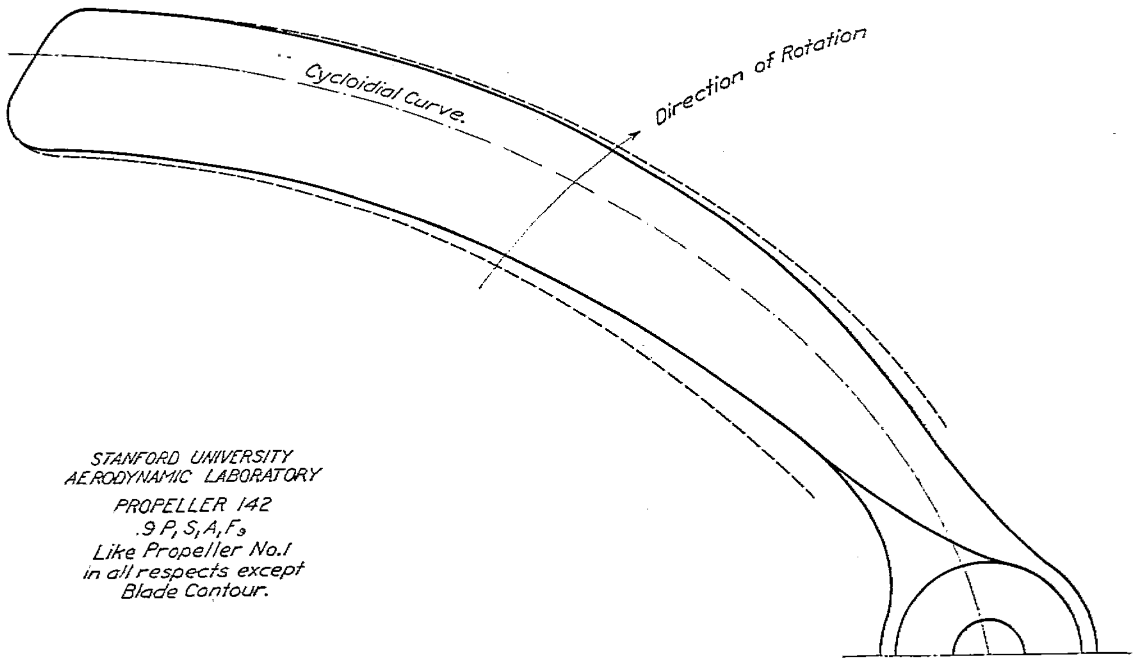

PLATE I.

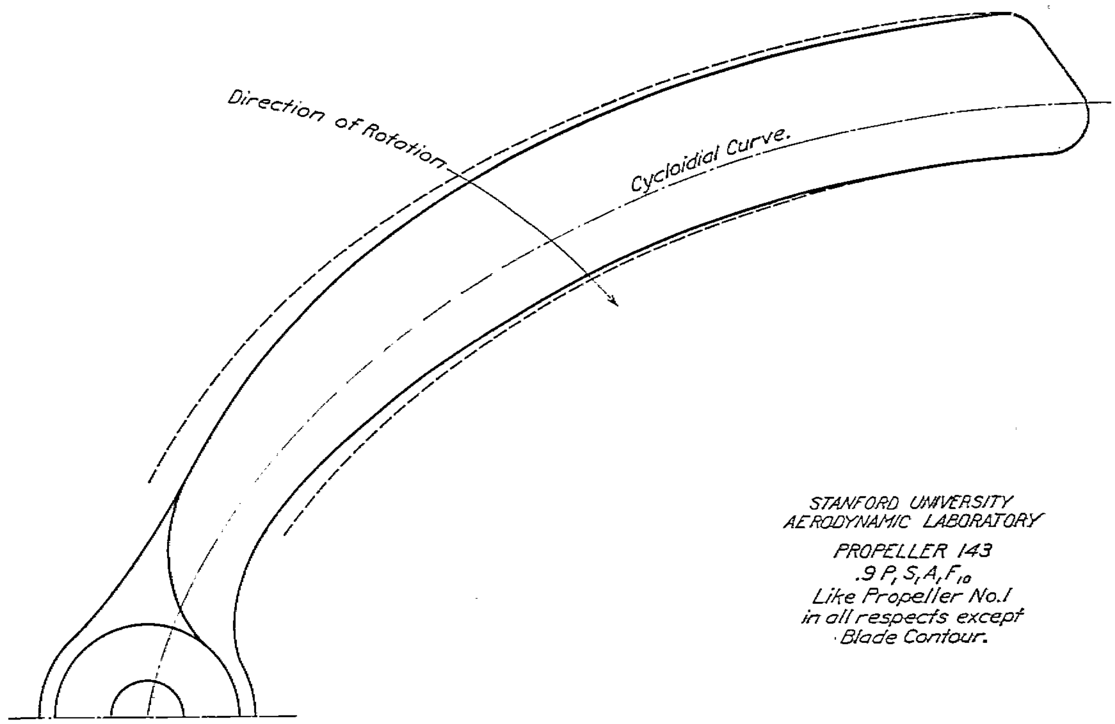

PLATE II.

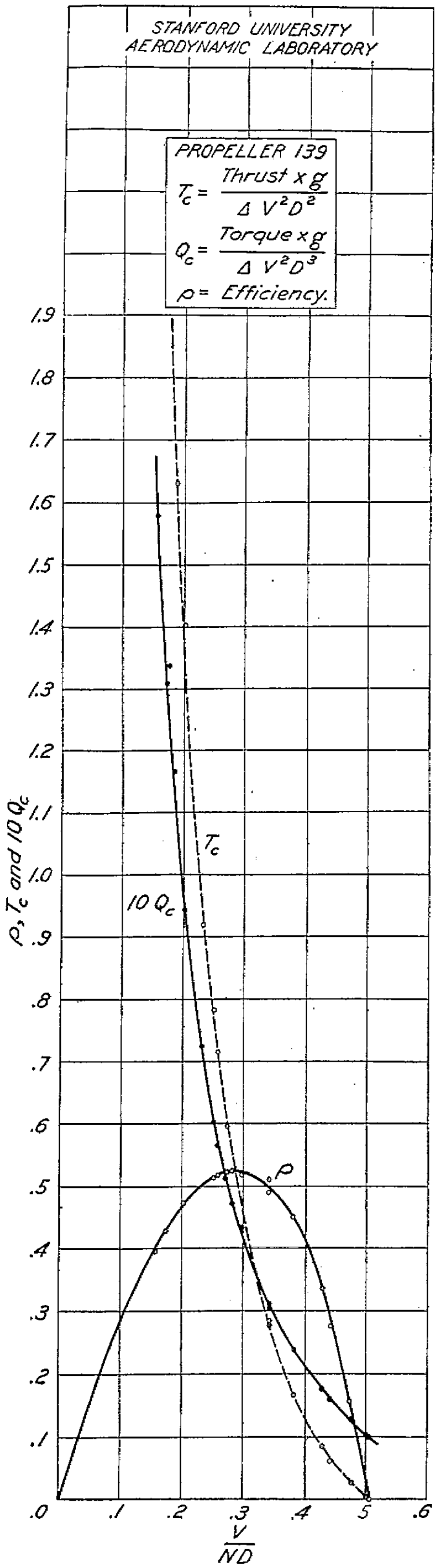

Plate III.

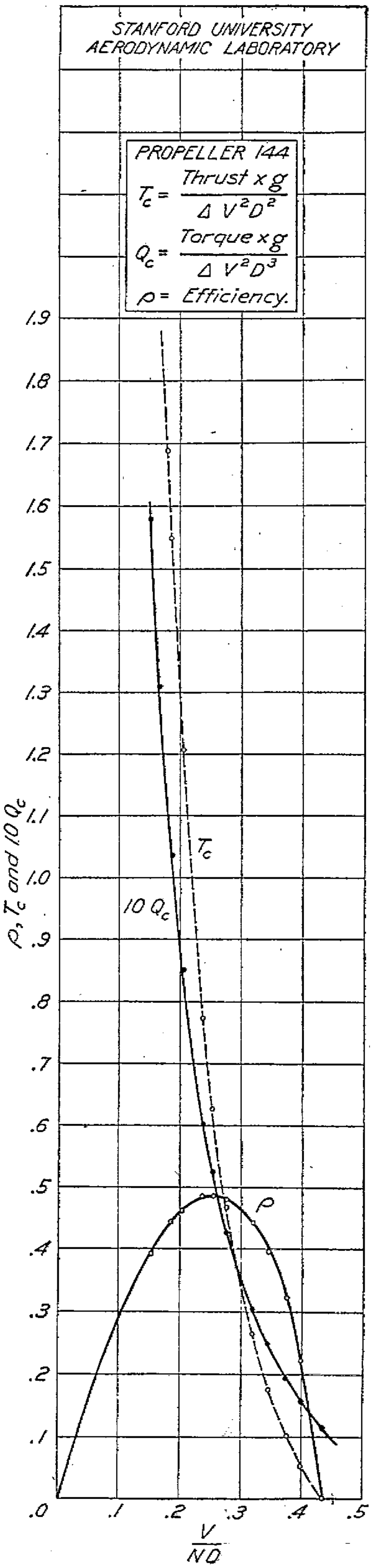

Plate IV.

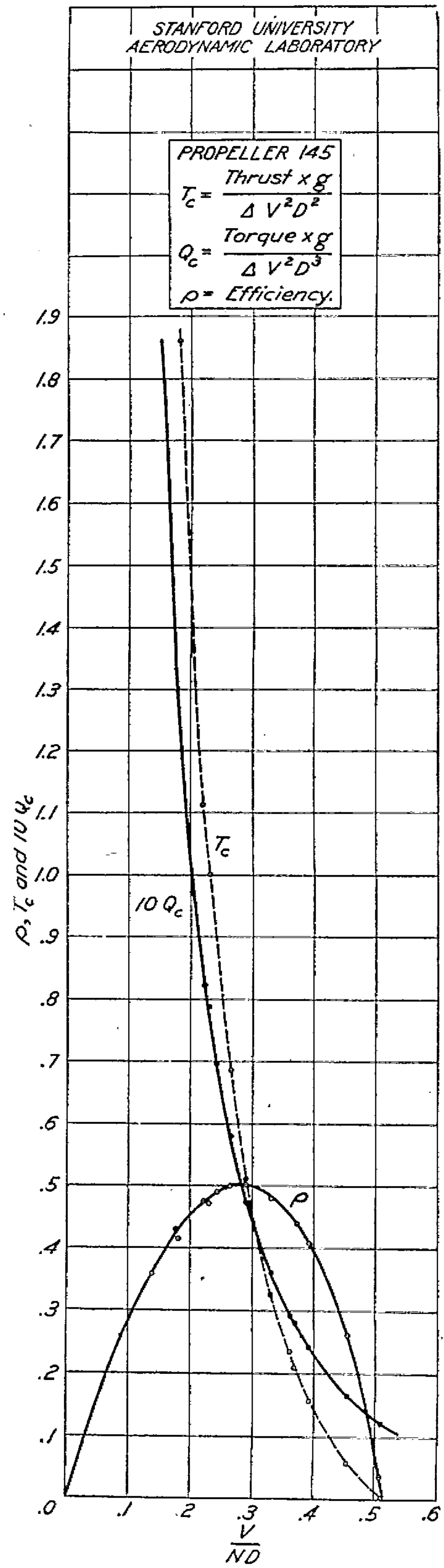

Plate V.

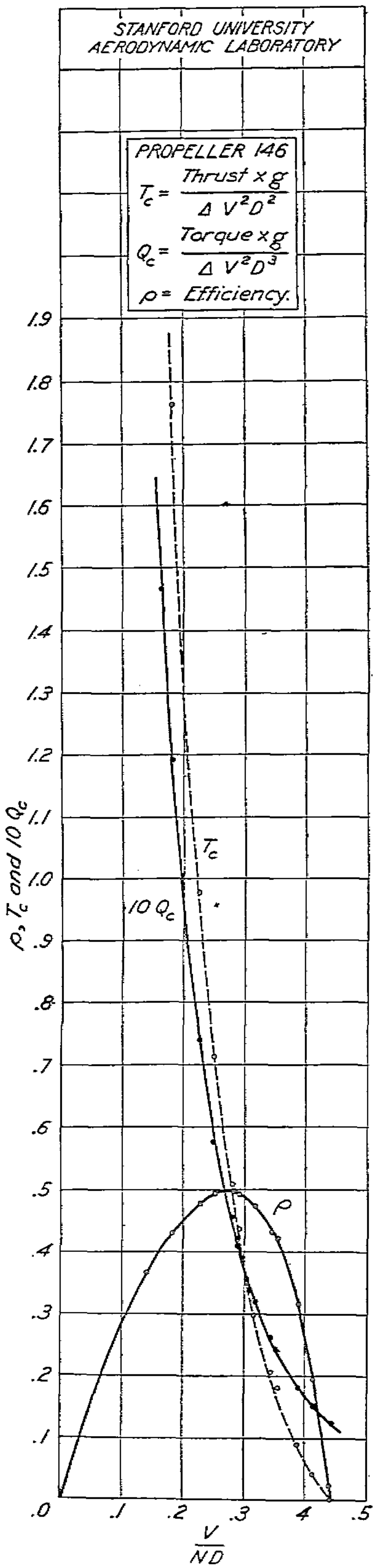

Plate VI.

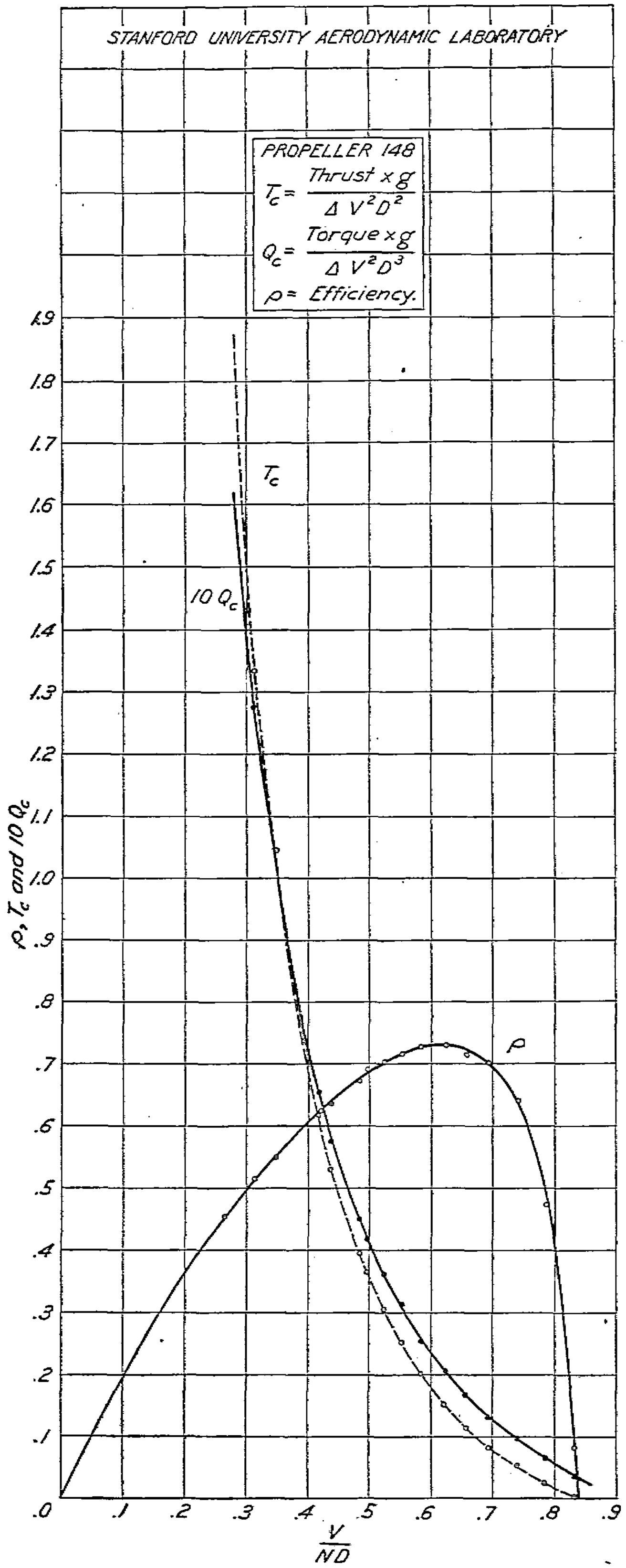

Plate VII.

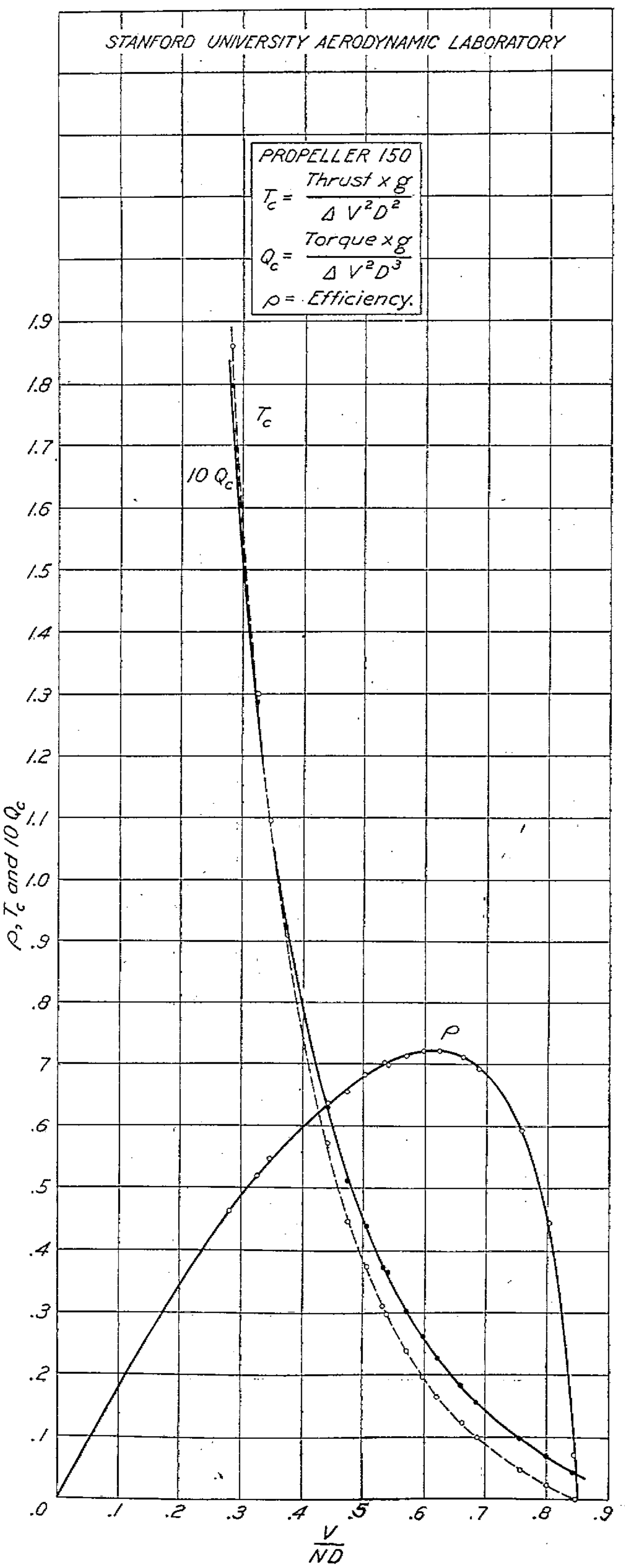

PLATE VIII.

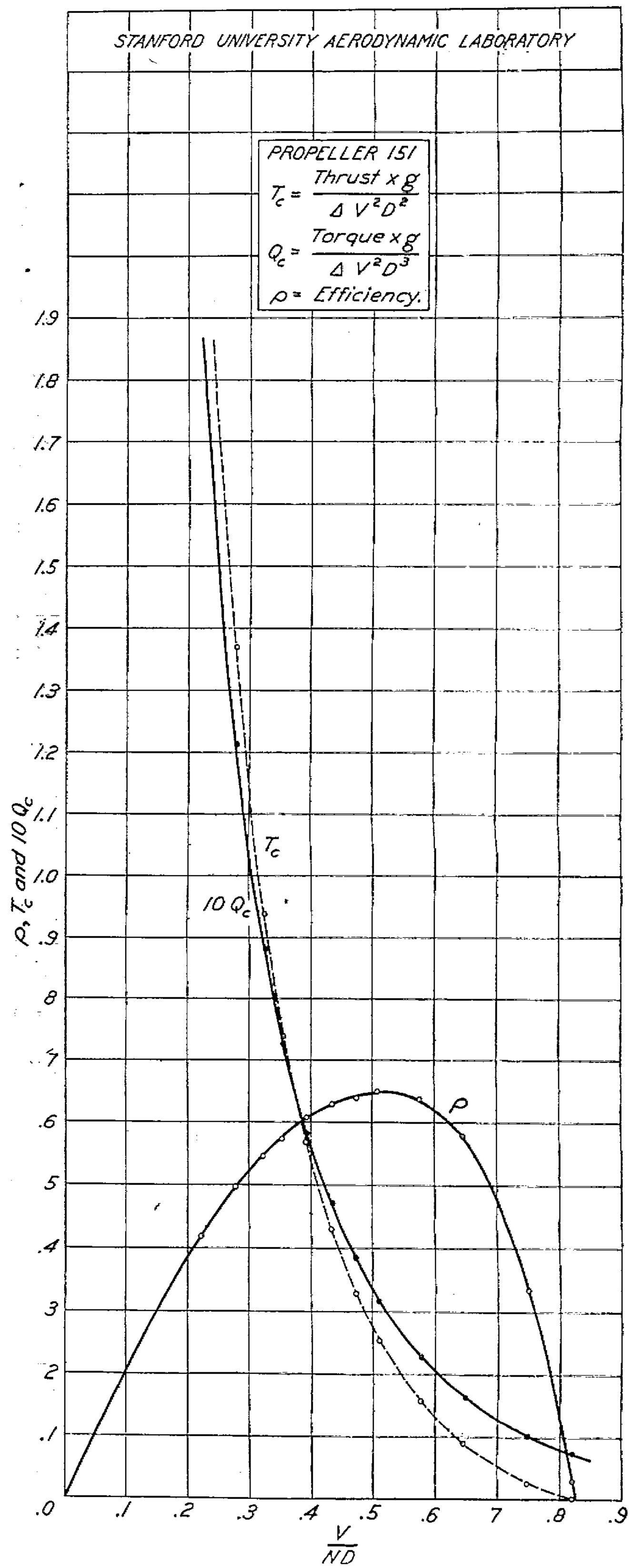

PLATE X.

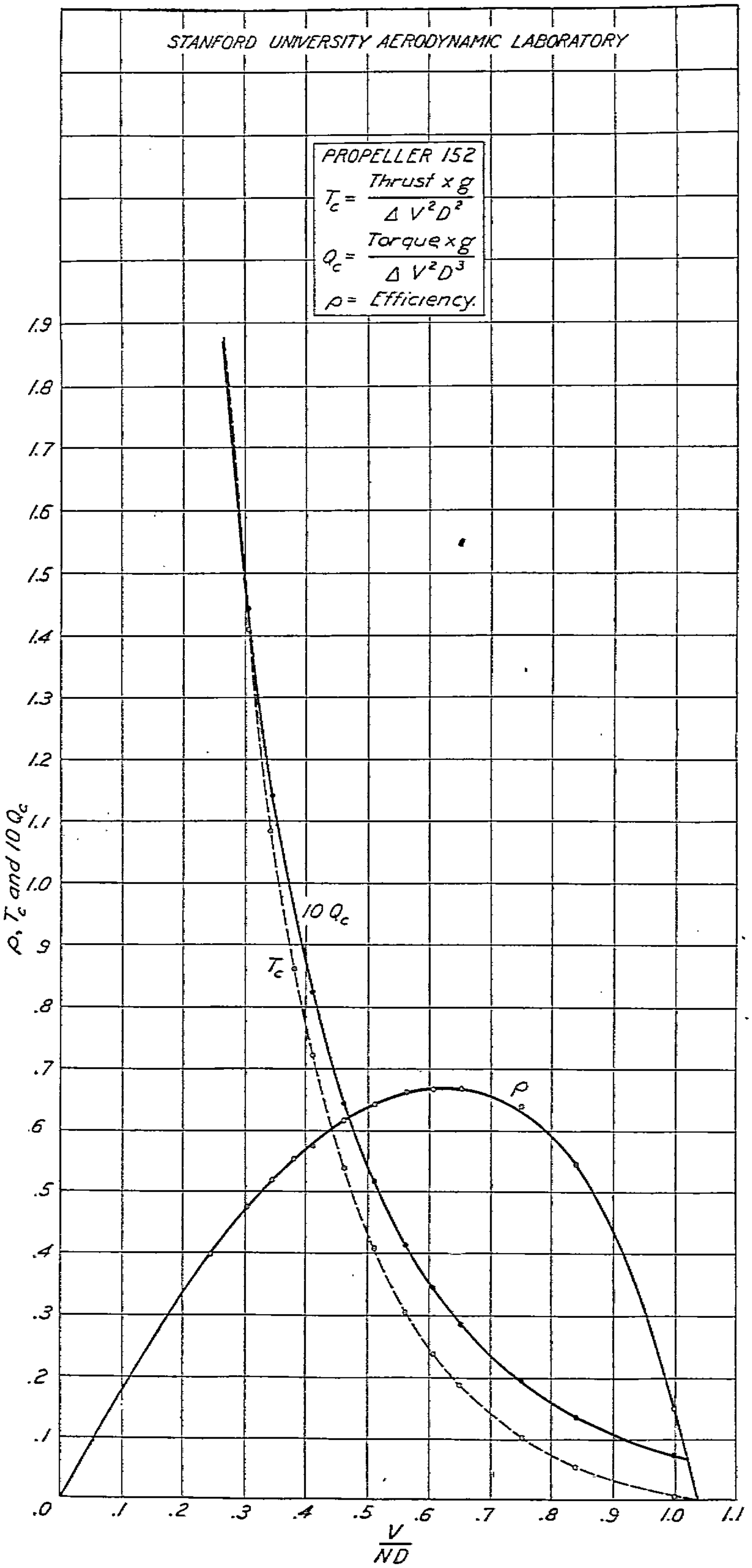
STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 152
$T_c = \frac{\text{Thrust} \times g}{\Delta V^2 D^2}$
$Q_c = \frac{\text{Torque} \times g}{\Delta V^2 D^3}$
ρ = Efficiency.
ρ, T_c and $10\,Q_c$
$10\,Q_c$
T_c
ρ
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
$\frac{V}{ND}$

PLATE IX.

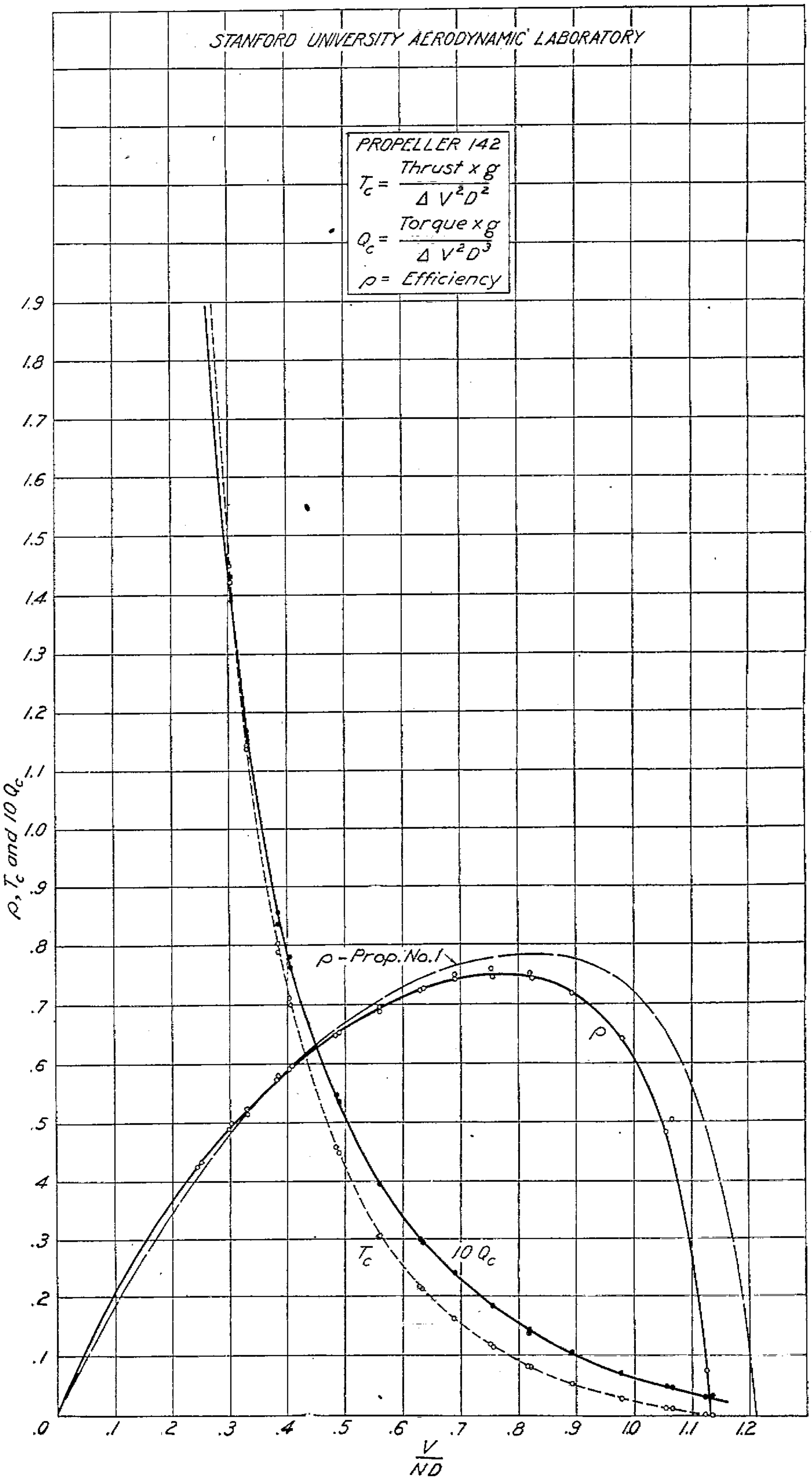
STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 142
$T_c = \frac{Thrust \times g}{\Delta V^2 D^2}$
$Q_c = \frac{Torque \times g}{\Delta V^2 D^3}$
ρ = Efficiency
ρ - Prop. No. 1
ρ
T_c
$10\,Q_c$
ρ, T_c and $10\,Q_c$
$\frac{V}{ND}$
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

PLATE XI.

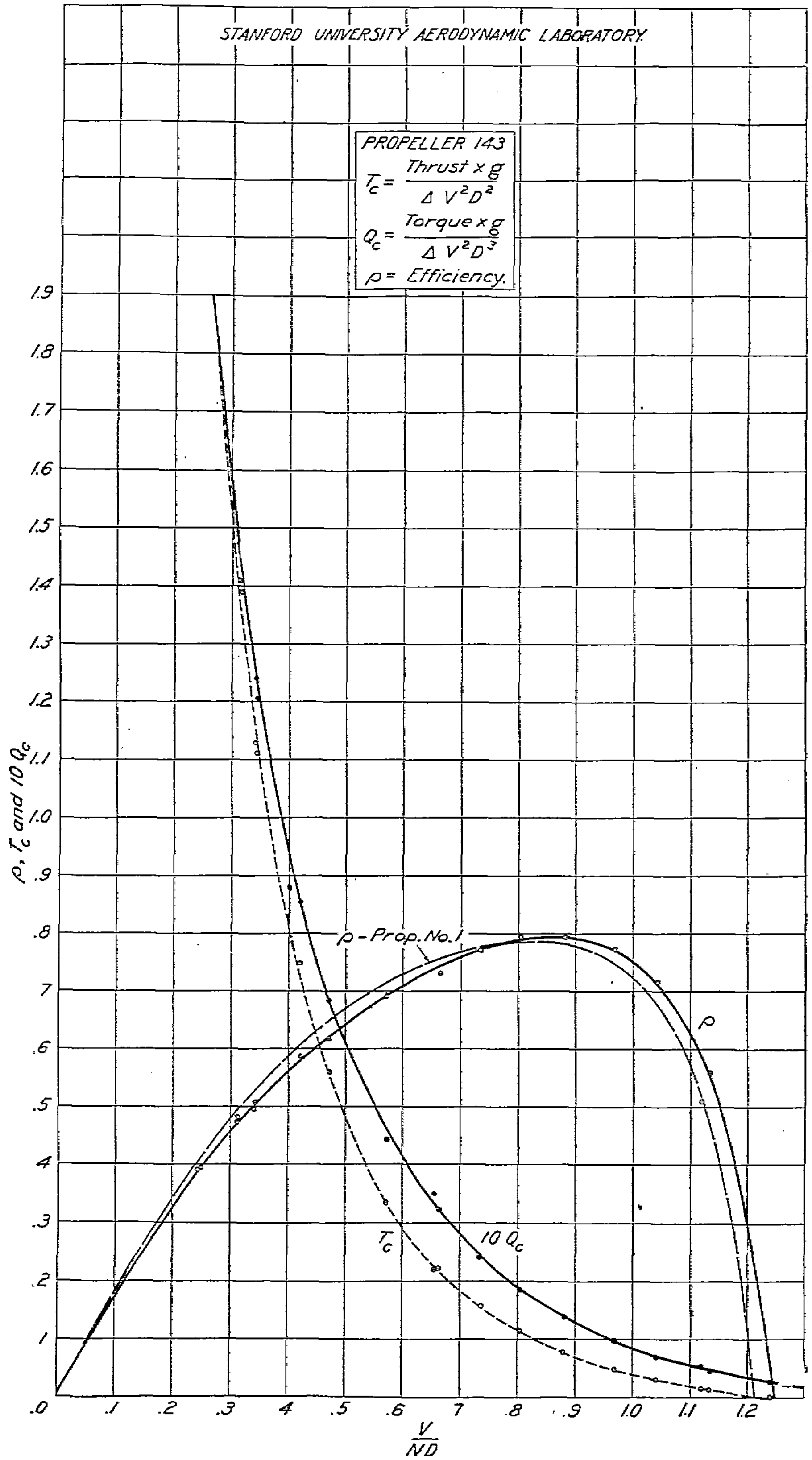
STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 143
$T_c = \frac{Thrust \times g}{\Delta V^2 D^2}$
$Q_c = \frac{Torque \times g}{\Delta V^2 D^3}$
ρ = Efficiency.
ρ, T_c and 10 Q_c
ρ - Prop. No. 1
ρ
T_c
10 Q_c
$\frac{V}{ND}$
.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

PLATE XII.